APPLICATION NOTE

Rotational Speed Sensors
KMI15/16

AN98087

Philips
Semiconductors

Abstract

The sensor modules of KMI 15 and KMI 16 series provide a simple and cost effective solution for rotational speed measurement in both automotive and industrial applications. They consist of a magnetoresistive sensor element, a permanent magnet fixed to it and an integrated signal conditioning circuit. Application relevant items such as mounting, electrical properties and possible encapsulation are discussed. Test results of the electromagnetic compatibility are shown and an interface circuit for improved protection of the sensor module is proposed.

APPLICATION NOTE

Rotational Speed Sensors
KMI15/16

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Summary

The rotational speed sensors KMI 15/x and KMI 16/x make use of the magnetoresistive effect. They consist of the magnetoresistive sensor element, a permanent magnet fixed to this sensor and an integrated signal conditioning circuit. The magnetoresistive principle offers a number of advantages compared with Hall-Effect sensors or inductive sensors such as measurements down to zero speed and a better signal to noise ratio.

The integrated signal conditioning electronics of the sensor modules KMI 15/x or KMI 16/x amplifies the small output voltage of the sensor element and converts it to a digital output signal. This signal is either a rectangular modulation of the supply current for two-wire technology (KMI 15/x) or a switched output voltage with open collector (KMI 16/x). Both sensor modules meet high the requirements of the automotive industry regarding electromagnetic compatibility to line conducted and radiated interference. Although the KMI sensor modules are designed for automotive applications, they also can be used advantageous for rotational speed measurement and movement detection in a wide range of industrial applications.

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1. INTRODUCTION

The KMI 15/X and KMI 16/x are magnetoresistive sensor modules with an integrated signal conditioning electronics to provide a simple and cost effective solution for rotational speed measurements. Due to their compact design, they are simple to design-in and therefore time-to-market is significantly reduced.

The KMI sensor modules consist of the magnetoresistive sensor element, a permanent magnet fixed to this sensor and the integrated signal conditioning circuit designed in bipolar technology. Compared with other sensing techniques, the magnetoresistive technology has a number of practical advantages such as:

- Wide air gap due to high basic sensitivity of the magnetoresistive effect
- Wide operating frequency range, including zero speed detection
- Insensitive to vibration
- Wide operating temperature range
- High EMC

The KMI sensor modules provide two different interfaces to the application. The KMI 15/x sensor modules have an interface using a digital modulation of the supply current and therefore require only a two-wire connection to the application circuit. This current interface is recommended if signals have transmitted over longer distances. On the other hand, also a 3-pin open-collector version (KMI 16/x) is available in order to fit more easily in standard applications. The signal conditioning IC and the sensor element are physically separated to improve high temperature performance of the KMI sensors. This construction ensures that the sensor element can be exposed to higher temperatures than the IC and power dissipation of the IC will not cause inhomogeneous heat in the sensor element.

The first part of this report gives an introduction into the principles of rotational speed measurement using magnetoresistive sensors. Then the characteristics of the magnetoresistive element and the on-chip signal conditioning circuits are described in more detail. Correct mounting of the sensor is another item to be taken into account from the application point of view. Some hints are given for correct encapsulation, including the effects and failures caused by non-ideal mounting. Another important item is the EMC performance of the sensor modules for which test results are given. Finally, a proposal is made for an advanced application circuit.

2. ROTATIONAL SPEED MEASUREMENT USING MAGNETORESISTVE SENSORS

Rotational speed measurement using magnetoresistive sensors (MR-sensors) is achieved by counting ferromagnetic marks, such as teeth of a passive gear wheel or the number of magnetic elements of magnetised ring. Beside magnetoresistive sensors also the inductive sensors and Hall-Effect sensors can be used for this task. However, the magnetoresistive effect offers some essential advantages which should be mentioned briefly.

First, the output signal level of a MR sensor does not vary with rotation speed, as it is the case in inductive sensor systems. Inductive sensors show a direct relation between the rotational speed and the output amplitude and therefore require sophisticated electronics to evaluate the large signal voltage range, especially in applications requiring low jitters.

MR-sensors, in contrast, are characterised by the fact that the sensor is static and the output signal is generated by the bending of magnetic field lines according to the position of the target wheel. This principle is shown in Figure 1. As bending of the magnetic field lines also occurs when the target is not moving, MR-sensors can measure very slow rotations, even down to 0 Hz.

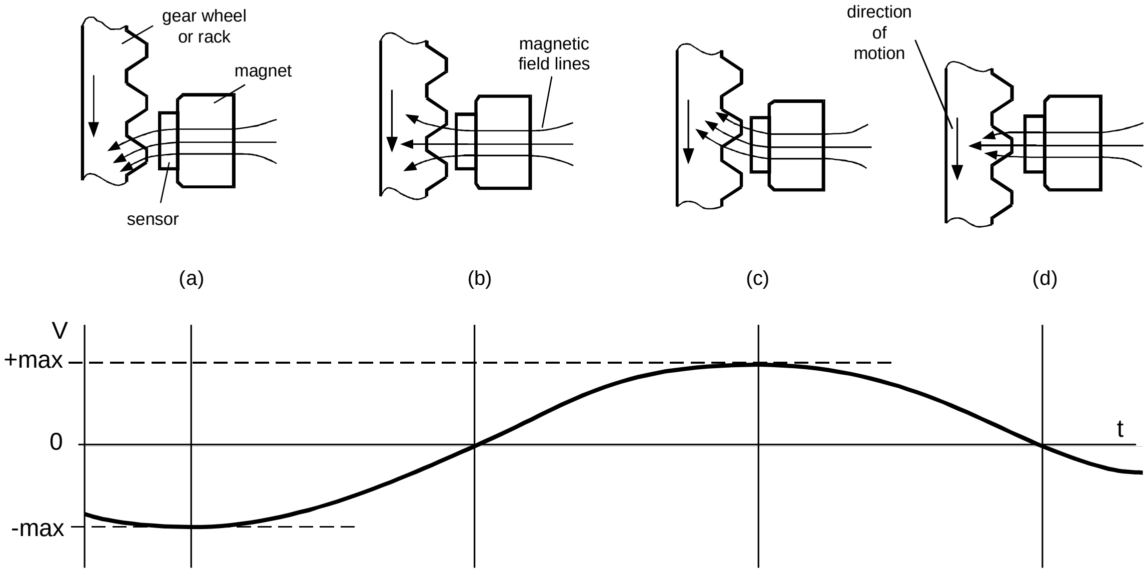

Figure 1: Sensor signal generation in MR-sensors

MR-sensors show larger output signals compared with Hall-Effect sensors as they have signal amplitudes of about 20 mV/kA/m. Hall-Effect sensors provide typically 0.4 mV/kA/m. The higher output voltage of the MR sensor means a much better signal to noise ratio of the sensor signal as well as improved EMC due to the higher signal levels. Moreover, it allows a much larger air gap between sensor and target at comparable target field strength. Consequently, also tolerances in the mechanical set-up and sensor housing may be larger, making the application simpler and reducing costs. Moreover, the necessary magnet is already attached to the sensor element, so that the KMI sensor modules are ready for use. Costs are further reduced as ferrite magnets can be used, rather than the expensive samarium cobalt magnets required for Hall-Effect sensors. All these advantages recommend MR-sensor modules for rotational speed measurements in a wide range of both automotive and industrial applications

The KMI sensor modules of Philips Semiconductors can also be used to measure direction of rotation. This requires two sensor modules placed to the target wheel at different positions. An extended signal conditioning electronic has to evaluate the phase difference between the signals of these two sensor modules.

3. MAGNETORESISTIVE ROTATIONAL SPEED SENSORS

3.1 The Magnetoresistive Sensor Element

3.1.1 The Magnetoresistive Effect

Magnetoresistive (MR) sensors make use of the magnetoresistive effect, the property of a current carrying magnetic material to change its resistivity in the presence of an external magnetic field. Figure 2 shows a strip of ferromagnetic material, called permalloy (20% Fe, 80% Ni).

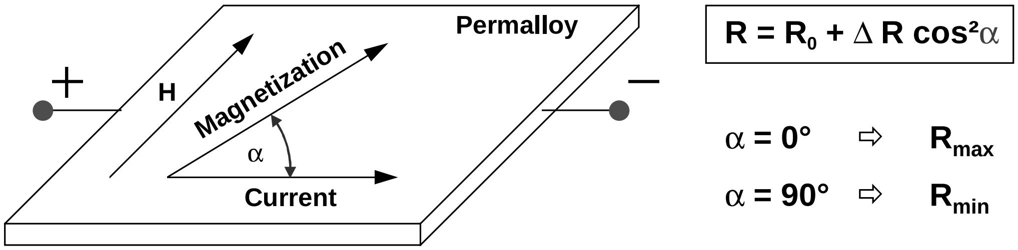

Figure 2: The magnetoresistive effect in permalloy

When no external magnetic field is present, the permalloy has an internal magnetisation vector parallel to the current. During deposition of the permalloy strip, a strong external magnetic field is applied parallel to the strip axis. This accentuates the inherent magnetic anisotropy of the strip and gives them a preferred magnetisation direction, so that even in the absence of an external magnetic field , the magnetisation will always tend to align with the strips. If an external magnetic field H is applied, parallel to the plane of the permalloy but perpendicular to the current flow, the internal magnetisation vector of the permalloy will rotate around an angle α. As a result, the resistance R of the permalloy will change as a function of the angle α, as given by:

$$R = R_0 + \Delta R \cdot \cos^2 \alpha$$

R_0 and ΔR are material parameters. ΔR is in the range of 2 to 3% of R_0.

3.1.2 Linearisation of Sensor Characteristic

It is obvious from this quadratic equation that the resistance to magnetic field relation is non-linear and in addition not unambiguous (compare with graph a) in Figure 4). To get a usable magnetic field sensor with a preferably linear characteristic, a more sophisticated design is necessary.

The magnetoresistive effect can be linearized by depositing aluminum stripes (called barber poles) on top of the permalloy strip at an angle of 45° to the strip axis. Figure 3 shows the principle. As aluminium has a much higher conductivity than permalloy, the effect of the barber pole is to rotate the current direction by 45°, effectively changing the angle between the magnetisation and the electrical current from α to (α - 45°). Graph b) in Figure 4 shows the impact on the sensor characteristic due to the barber pole structure.

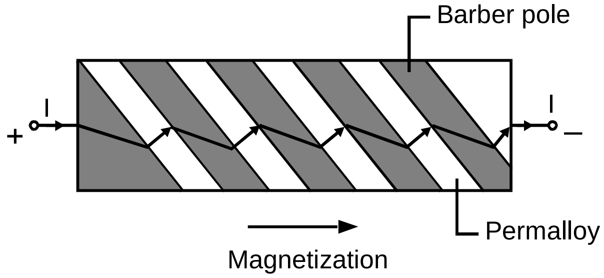

Figure 3: Linearization of the magnetoresistive effect

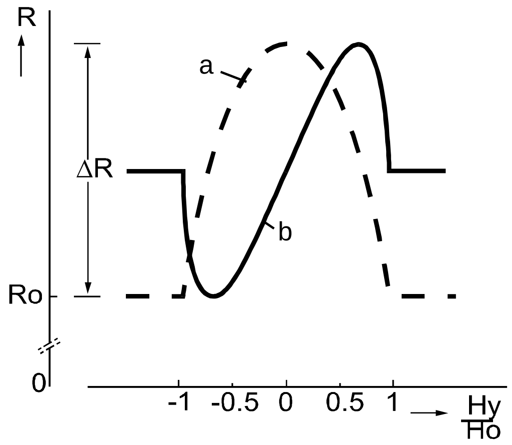

Figure 4: a) R-H characteristic of a standard sensor, b) R-H characteristic of barber pole sensors

To build up a complete sensor element, a Wheatstone bridge arrangement consisting of four magnetoresistive elements is used. In this arrangement, diagonal elements have barber poles of the same orientation. This means that one diagonal pair has barber poles orientated +45° to the strip axis, while the other pair has an orientation of -45°. This ensures a doubling of the output signal while still having an almost linear output signal. Moreover, the inherent temperature coefficients of the four bridge resistances are mutually compensated.

3.1.3 Flipping

Although the “flipping” of MR sensors does not affect the KMI sensor modules due to their stabilisation magnets, the effect should be mentioned for completeness.

The internal magnetisation of the sensor strip has two stable positions. So, if for any reason the sensor is influenced by a powerful magnetic field opposing the internal field, the magnetisation may switch or ”flip” from its present direction into the opposite direction. As demonstrated in Figure 5 this leads to a reversal of the sensor characteristic. Consequently, to ensure stable operation, it must be avoided to operate the sensor in an environment where the sensor is subjected to strong negative external fields (”-Hx”). Preferably, a positive (”+Hx”) auxiliary field of sufficient magnitude should be applied to prevent any likelihood of flipping within the intended operating range of Hy.

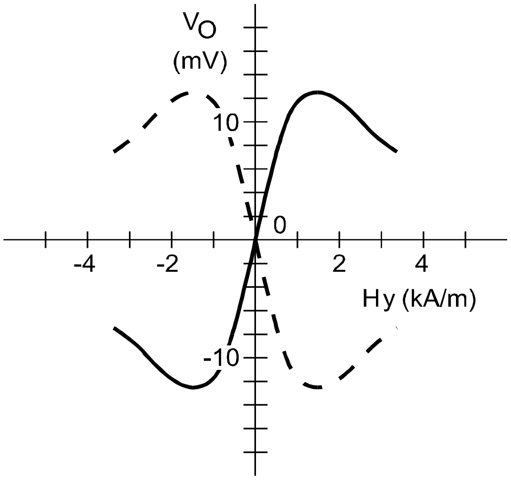

Figure 5: Reversal of sensor characteristic caused by flipping

For the sensor types KMI 15/1, KMI 15/4 and KMI 16/1, this stabilisation field is provided by a magnetic field component in x-direction of the operation magnet. This is field component is attained by an angled magnetisation (see Figure 7). The types KMI 15/2 and KMI 16/2 intended for active targets and therfore not requiring a magnet for operation, are fitted with a smaller auxiliary permanent magnet, magnetised in X-direction only.

3.2 Principle of Speed Measurement

The MR-sensor cannot directly measure rotational speed but is sensitive to the motion of toothed wheels made from ferrous material (passive targets) or rotating wheels having alternating magnetic poles (active targets).

3.2.1 Passive Targets Wheel

The principle of operation has already been briefly discussed in section 2. Figure 1 shows the general arrangement for a passive target wheel.

The sensor is fitted with a permanent magnet. Without a ferromagnetic target or a symmetric position of the toothed wheel, no component of the magnetic field would be in the sensitive direction (y-direction) and therefore the sensor output would be zero. For non-symmetric positions, for example if the passive target rotates in front of the sensor, the magnetic field is bent according to the actual wheel position and an alternating field component in the y-direction arises. This alternating field component is used to generate an output signal that varies according to the wheel position. The amplitude of the sensor output voltage depends on the magnetic field strength of the biasing magnet, the distance between sensor and target and, obviously, on the structure of the target. Large solid targets will give stronger signals at larger distances from the sensor than small targets.

The terms to describe the structure of a gear wheel are explained in TABLE 1 and Figure 6. Figure 7 shows the enlarged drawing of the complete sensor module for passive target wheels. The direction of magnetisation ensures a component of the magnetic field in x-direction to prevent the sensor from flipping (compare with section 0).

SYMBOL	DESCRIPTION	UNIT
DIN		
z	number of teeth	
d	Diameter	mm
m	module m= d / z	mm
p	pitch p = p m	mm
ASA		
PD	pitch diameter	inch
DP	diametric pitch DP = z/PD	1/inch
CP	circular pitch CP = p/DP	inch
For conversion from ASA to DIN : m = 25.4 mm/DP ; p = 25.4 x CP		

TABLE 1: Gear wheel dimensions

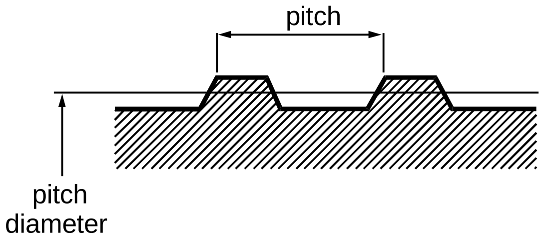

Figure 6: Gear wheel dimensions

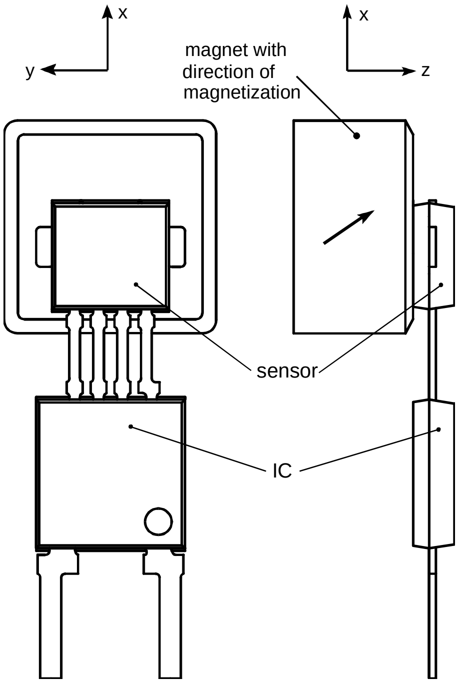

Figure 7: Component detail of the sensor KMI15/1 for passive target wheels

3.2.2 Active Target Wheel

In contrast to passive targets that are not magnetised, active targets show alternating magnetic poles as described in Figure 8. Here the target provides the “working” field and no magnet is required for operation. However, in order to prevent the sensor from, a small stabilisation magnet is still applied to the sensor. Figure 9 shows the KMI 15/2 sensor module intended for use with an active target wheel.

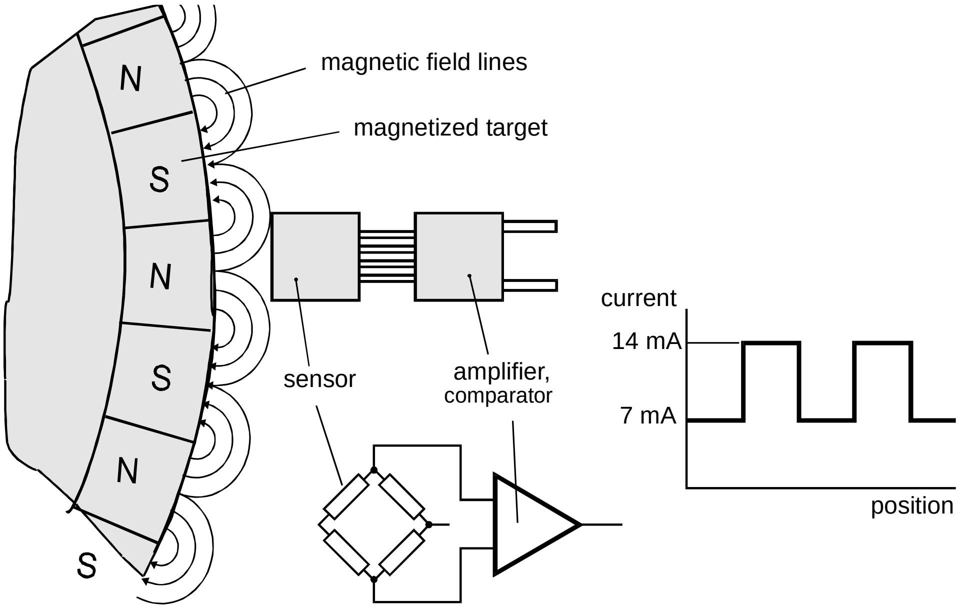

Figure 8: Rotational speed measurement using an active target wheel

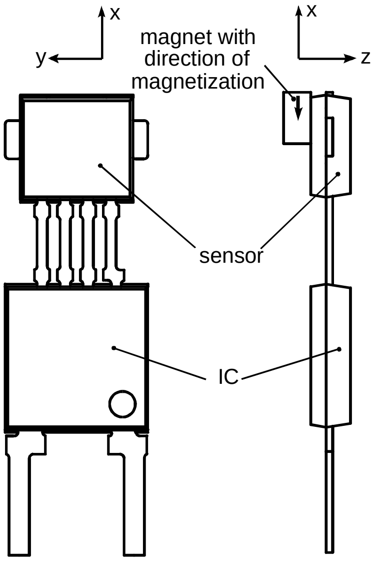

Figure 9: Component detail of the KMI 15/2

The structure of an active target can be expressed similarly to that for passive targets (see TABLE 1). In this case, a north-south magnetic pole pair represents a tooth-valley pair.

The achievable maximum sensing distance for an active wheel depends on the field strength and the structure of the magnetic poles. Figure 10 gives the relation between maximum air gap and pitch for typical plastoferrite rings. This graph was found by averaging measurement results of different target wheels.

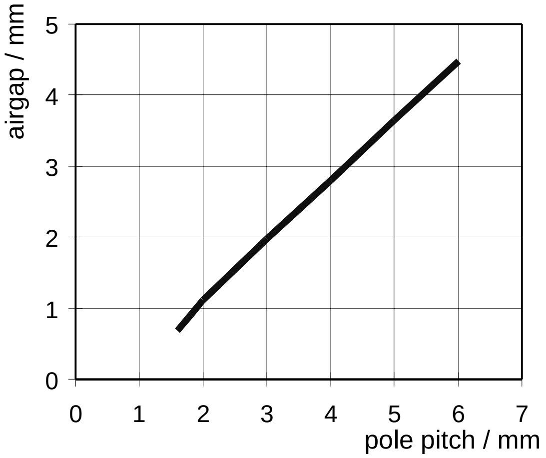

Figure 10: Maximum air gap versus pole pitch for active target wheels.

3.3 The Integrated Signal Conditioning Circuit

The rotational speed sensors KMI 15/x and KMI 16/x include an advanced bipolar signal conditioning circuitry. The KMI 16/x sensor modules provide an open collector output, while KMI 15/x sensor modules have a current interface that requires only two-wires to connect them in the application.

Figure 11 shows the block diagram of the KMI 15/x sensor modules, while the block diagram of the KMI 16/x modules is given in Figure 12. The only difference between both is that for the KMI16/x the switchable current source, which generates the modulated output current signal, is replaced by an open collector output. Moreover, the KMI 16/x sensors allow operation at 5V supply voltage and therfore directly provide a digital output at standard voltage levels.

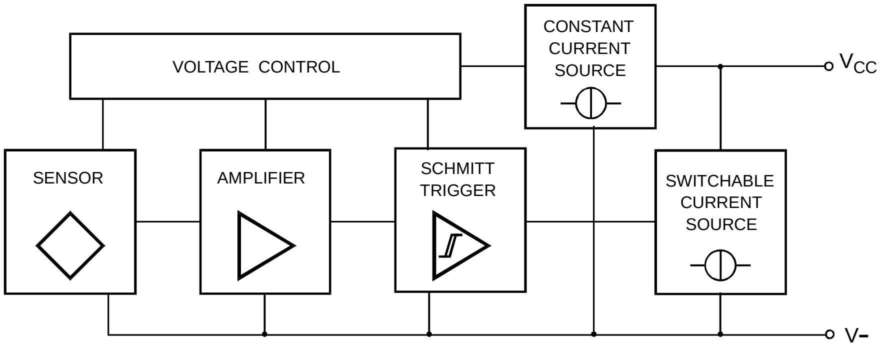

Figure 11: Block diagram of the KMI 15/x sensors with current interface

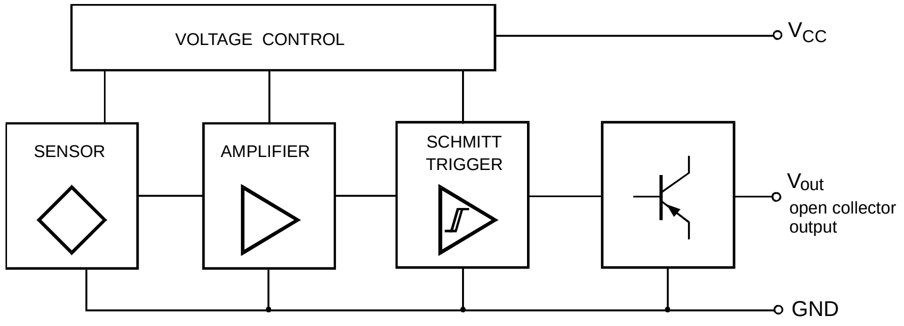

Figure 12: Block diagram of the KMI16/x sensors with open collector output.

Figure 13 shows a more detailed circuit diagram of the KMI 15/x sensor modules. After passing the EMC filter, the sensor signal is amplified and then digitised by a comparator. The comparator has a built-in hysteresis in order to avoid switching due to noise. The voltage control block is stabilised by a bandgap reference diode. It provides the 5 V power supply for the sensor, the amplifier and the comparator. The KMI 15/x modules use two current sources. One current source generates a basic current of 7 mA, which is used for the internal power supply. The current of the second, 7 mA current source is added when triggered by the digitised sensor signal. Thus, during operation, the output current, Icc, switches between 7 mA and 14 mA.

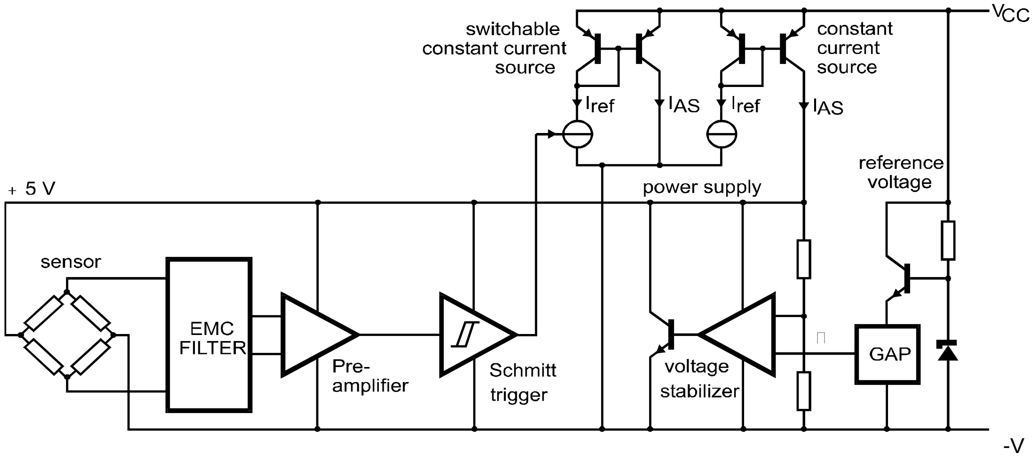

Figure 13: Sensor signal conditioning circuit of the KMI 15/x sensors

3.4 Product Overview

TABLE 2 gives an overview on the complete KMI family. As explained in the previous sections, the KMI 15/x types offer a current source output requiring only two wires for connection. The KMI 16/x sensors have separate signal outputs implemented as open collectors. For each of these interface types, there is at least one sensor module available for passive target wheels and another type for active target wheels. These sensor modules differ only by size and magnetisation direction of the magnet fitted to it.

Type	Interface	Target Wheel	Sensing Distance in mm	Package	Availability
KMI 15/1	Current source	Passive ferrom.	2.5	SOT453	Now
KMI 15/2	Current source	Magnetised	2.5	SOT453	Now
KMI 15/4	Current source	Passive ferrom.	2.0	SOT453	Now
KMI 16/1	Open collector	Passive ferrom.	2.5	SOT477	Now
KMI 16/2	Open collector	Magnetised	2.5	SOT477	Q1 ‘99

TABLE 2: Product overview

3.5 Limiting Electrical Conditions and Protection

The following Table 3 shows the limiting conditions for the KMI15 and KMI16.

Item	KMI16/x	KMI15/x	Remarks
Supply Voltage	4.5V to 16V	5.5V to 16V	
Load Dump Protection	Yes*	Yes*	*Max. 40V, 2s
Reverse Polarity	No	No	

Table 3: Limiting Conditions of KMI15 and KMI16

4. PROPERTIES OF THE SENSOR MODULES

4.1 Sensing Distance and Hysteresis

The sensing distance d is defined as the distance between the front of the sensor and the tips of the teeth, measured on the central axis of the magnet (see Figure 14). Above a certain value of d, Icc ceases to vary between 7 mA and 14 mA and remains constant at one of these values. The sensor signal, which decreases with larger sensing distances, has become too small to be recognised by the signal conditioning electronics.

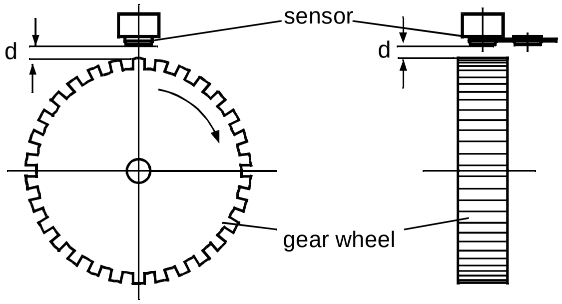

Figure 14: Definition of the sensing distance d

The KMI 15/x and KMI 16/x sensors are able to generate a stable digital output signal in a large range of sensing distances. They have a built-in hysteresis to avoid unwanted switching of the sensor due to

- Mechanical vibration of the sensor or the gear wheel
- Electrical interference
- Circuit oscillation at very low rotational speed

A larger hysteresis provides a better immunity to disturbances but, on the other hand, reduces the maximum sensing distance d, as the sensor signal must exceed the hysteresis levels to be recognised. Consequently, a compromise has to be found between hysteresis and sensing distance.

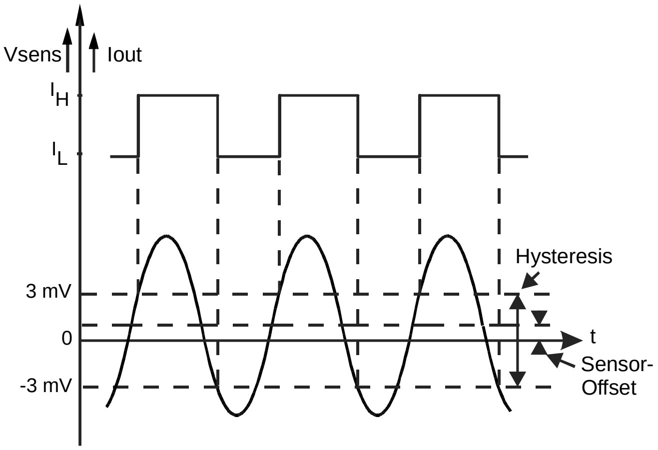

Figure 15: Sensor output voltage and hysteresis

For the KMI sensors, the hysteresis is set to +/- 3 mV at room temperature (see Figure 15). Consequently, the maximum attainable sensing distance is achieved when the sensor signal reaches the level of 6 mV peak-to-peak. Note that this limit assumes a zero sensor signal offset.

4.2 Temperature Coefficient

MR-sensors have negative temperature coefficients of about -0.4 %/K. This means that the amplitude of the sensor signal goes down at higher temperatures. Without compensation, or in other words, without an adaptation of the hysteresis levels, this effect would reduce the maximum sensing distance d at higher temperatures. Therefore the KMI sensor modules provide an automatic adaptation of the hysteresis levels with temperature. Figure 16 shows the residual temperature dependency of the maximum sensing distance.

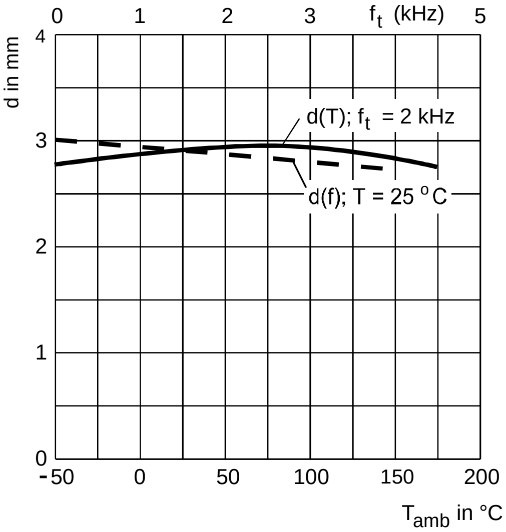

Figure 16: Maximum sensing distance d as a function of temperature and tooth frequency (KMI 15/1)

4.3 Eddy Currents

The movement of the ferromagnetic wheel in the magnetic field of the sensor system will induce eddy currents in the wheel. These eddy currents also cause a (secondary) magnetic field, superimposed to the operating field in the sensor. This secondary field generates an offset voltage in the sensor signal. The eddy currents and therefore the resulting offsets are nearly proportional to the rotational speed of the wheel. As a result, this effect slightly reduces the maximum sensing distance at higher frequencies. The function between rotational speed and maximum sensing distances is also shown in Figure 16.

The direction of the eddy currents and consequently sign of the generated secondary magnetic field depends on the direction of rotation. This means that the external field can increase or compensate a residual offset voltage of the sensor and therefore may cause a direction dependent change of the maximum achievable sensing distance. Consequently, also the duty cycle of the output signal of nominal 50% (without any offset) may slightly depend on the direction of movement.

4.4 Gear Wheel Structure

Finally the structure of the gear wheel itself will affect the maximum sensing distance. Figure 17 shows the variation of the maximum sensing distance d in dependence of the module m for a KMI15/1 sensor. Large solid targets will give stronger signals than small targets. In general, the “size” of the structure can be described as a relationship between wheel diameter and the number of teeth (see also TABLE 1: Gear wheel dimensions).

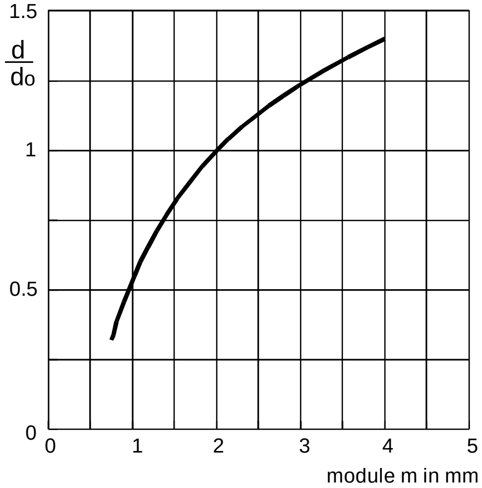

Figure 17: Normalised maximum sensing distance as a function of the module m for the KMI 15/1-sensor module

4.5 Position Tolerances

The optimum position of the sensor is symmetrical to the target wheel with respect to all degrees of freedom. Deviations from this position may reduce the amplitude of the MR-sensor output or increase signal offset, which, in consequence, reduces the maximum sensing distance. Significant larger or smaller values for the duty cycle of nominal 50% indicate that there is an additional offset caused by wrong mounting. There are three possible mounting errors that have to be taken into account:

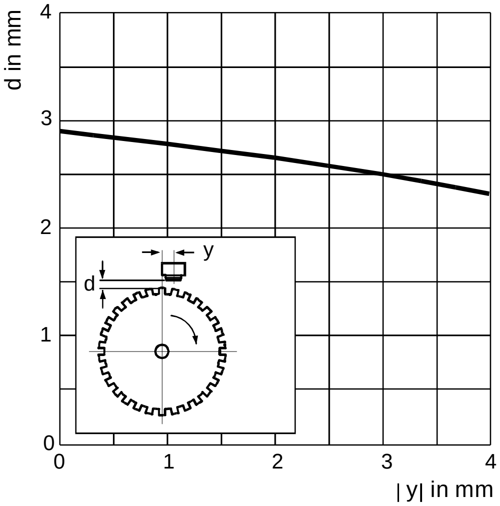

Figure 18: Sensing distance as a function of positional tolerance in the y-axis for a KMI15/1-sensor module.

The first possible error is a shift in y-direction relative to the optimum sensor position as defined in Figure 18. The graph in Figure 18 shows the sensing distance as a function of an y-axis shift. It is recommended to keep this shift smaller than 0.5 mm in order not to have a significant loss of performance.

The second effect to be taken into account is an angular error as defined in Figure 19. This error should be kept smaller than 1 degree for adequaete operation.

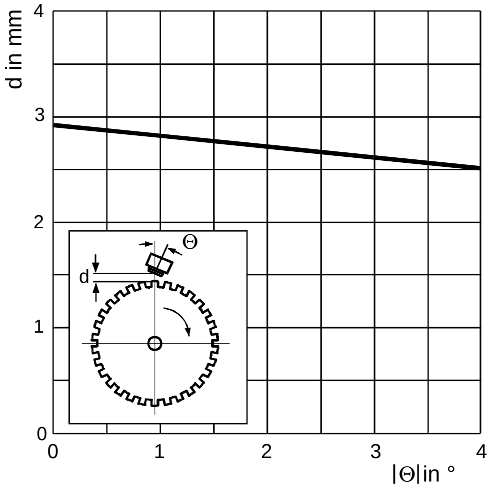

Figure 19: Sensing distance as a function of the angular error for the KMI15/1

An axial shift of the position in x-direction is not very critical with respect to the performance of the KMI sensor modules. Figure 20 shows the definition of this position error and gives some values for the KMI15/1. The graph is non-symmetrical due to the effect that a field component in x-direction already exist to prevent the sensor from flipping and this partitioning is changed by this position error. The optimum position is x = 0.

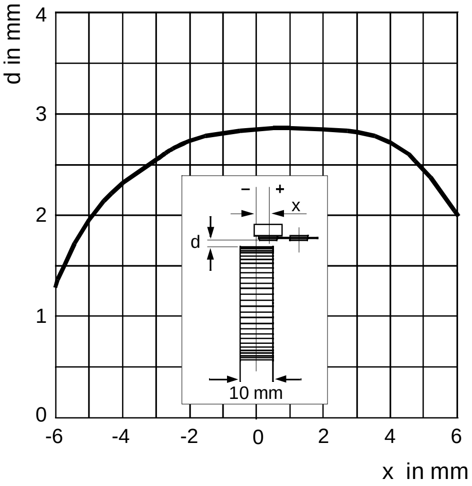

Figure 20: Sensing distance as a function of positional tolerance in the x-axis

A tilt in y-z plane has negligible impact on the sensing distance for angles less than 4°. Therefore, this error normally has not to be considered.

4.6 External Magnetic Fields

External magnetic fields if present are added to the operating field and therefore may cause an additional offset voltage. If this offset exceeds a certain limit (see e.g. Figure 15) an unacceptable change in duty cycle or even malfunction may occur. Sources of external magnetic fields are all kind of permanent magnets and electromagnetic devices like motors and relais, but also simple wires carrying high currents may cause significant magnetic fields. What level of disturbances is tolerable depends on the sensing distance required. In general, sensor modules should be mounted as far away as possible from all sources of magnetic fields. What external field strength is tolerated depends on the sensing distance required and therefore must be decided individually.

Another aspect to be taken into account is that very strong external fields may damage the sensor as they may permanently change the magnetisation of the attached permanent magnet. Magnetic fields up to a field strength of H = 5 kA/m are tolerated regarding this issue but already may significant influence the sensor performance.

5. ENCAPSULATION OF THE KMI SENSORS

5.1 Plastic Encapsulation

The KMI rotational speed sensor comes in special package patented by Philips that is predestined for customer specific encapsulation. Thanks to this package, the sensor modules are highly insensitive to mechanical stress. They can be easily built into a customised moulding, but some precautions should be taken into account to ensure full performance.

During plastic encapsulation the plastic material must not be injected directly to the MR-sensor or the integrated circuit because this may cause remaining mechanical stress in these parts. Furthermore it had to be ensured that the high temperature of the injected plastic material does not affect the durability of the gluing of the auxiliary magnet. High temperature and pressure could change the position of the magnet and therefore may damage the offset trimming.

The MR-sensor element is placed directly on the leadframe. Two reference points, which are part of this leadframe, can be used in the system design as reference mark. As the tolerances of the plastic encapsulation are no longer part of the overall tolerance calculation, this effect allows a precise sensor positioning and consequently a larger air gap.

Figure 21 shows the drawing of the lead frame with the reference points, the MR-sensor, the integrated signal conditioning circuit and the sensor package. The exact mechanical dimensions can be found in the current data book.

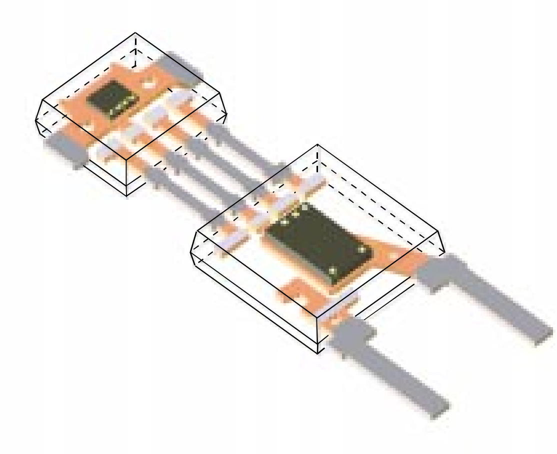

Figure 21: Construction and encapsulation of the KMI sensor modules.

5.2 Bending of Connection Pins

The electrical connections between the MR-sensor and the integrated circuit can be bent to adapt the sensor element position to the actual application. However, the maximum force to the connections between sensor element and IC must be limited to F=20 N in order not to destroy the device during this process.

The external connections to the supply pins should be fixed by clamping in order to avoid any tractive force to the leadframe in the sensor package. The maximum force allowed for this pins is F = 50 N.

The limiting values for bending are given in the following Figure 22.

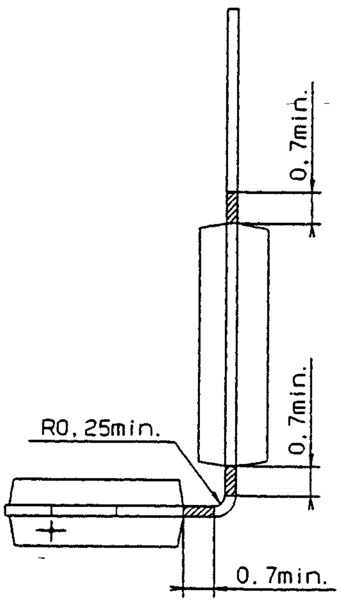

Figure 22: Limiting conditions for bending

6. APPLICATION CIRCUIT AND ELECTROMAGNETIC COMPATIBILITY

6.1 Test and Application Circuit

Figure 23 shows a test circuit to convert the current signal of the KMI 15/x sensor modules into a voltage. Figure 24 shows the respective circuit for the KMI16/x with open collector. Dependent on the actual conditions in the application, these simple circuits must be extended by protective components. An example for automotive applications is given in the next section.

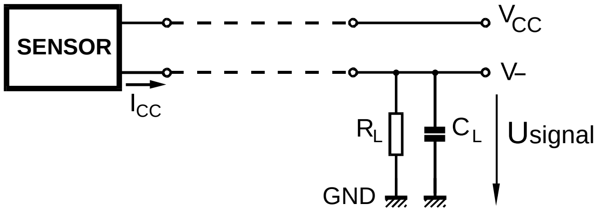

Figure 23: Test circuit for KMI15/x

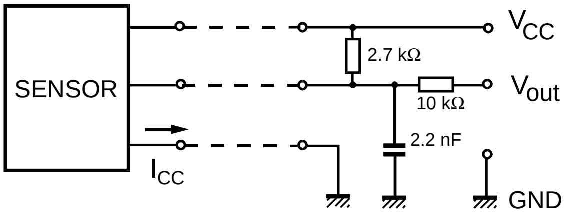

Figure 24: Test Circuit for KMI 16/x

6.2 Line Conducted Interferences

Figure 25 shows the recommended application circuit for KMI 15/x sensor modules in automotive applications. It adds some measures to improve electromagnetic compatibility. Spikes of positive or negative polarity are suppressed and also a protection against reverse polarity of the supply voltage is included.

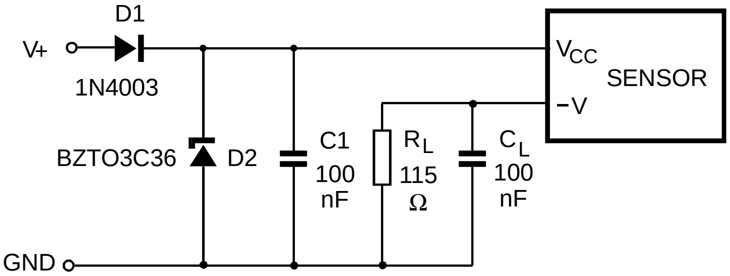

Figure 25: Recommended application circuit for the KMI15/x sensors

TABLE 4 lists the test results found for this circuit for line-conducted disturbances according to ISO 7637-1. It should be noted that this circuit does not protect the device against the “load dump pulse” (test pulse 5 according to ISO 7637-1). Protection against this pulse would require a special suppressor diode with sufficient energy absorption capability. However, as board nets of cars often already contain a central load dump protection that limits the pulse voltage to Vmax = 40 V, this kind of protection is not required in any case.

EMC REF. ISO 7637-1	**MIN. (V)**	**MAX.(V)**	**Remarks**	**Severity class**
Test pulse 1	-100	-	td = 2 ms	C
Test pulse 2	-	100	td = 0.2 ms	A
Test pulse 3a	-150	-	td = 0.1 µs	A
Test pulse 3b	-	100	td = 0.1 µs	A
Test pulse 4	-7	-	td = 130 ms	B
Test pulse 5		120	td = 400 ms	see text

TABLE 4: Test results regarding line conducted interferences

6.3 Radiated Interference

Any sensitive electronic system connected to other equipment by cables is exposed to electromagnetic disturbances. The KMI 15/x and KMI 16/x sensor modules provide RF-filter in the input stage to avoid negative effects on the system performance. The sensors were tested under standardised conditions in a “strip-line” according to ISO 11425-5. Tests were passed at a maximum field strength of E = 150 V/m with and without AM modulation (1kHz, 95%). Actual applications, however, may lead to different results due to special environment characteristics such as resonance effects. Therefore it is strongly recommended to do final tests regarding EMC in the application relevant environment.

6.4 Electrostatic Discharge

During handling and mounting electrostatic charges may affect the sensor pins and under extreme conditions even damage or destroy the sensor. Tests for electrostatic discharges (ESD) were conducted in line with IEC 801-2 to safeguard the handling capability of the KMI sensor modules. The IEC 801-2 test conditions were:

C = 150 pF, R = 150 Ω. V = 2 kV

These data are only valid for the supply pins, but no protective means are provided for the connections between sensor element and the IC. Common rules for handling electrostatic sensitive devices must be observed.

7. INTERFACE TO DIGITAL SIGNAL PROCESSING FOR KMI 15/X

7.1 General

The integrated rotational speed sensor KMI 15/x provides a modulated current. For subsequent digital signal processing, this current signal has to be converted to a ground referenced voltage signal, matching the logic levels of the processing unit. Additionally, the signal conditioning circuit should include a low pass filter in front of the comparator input and protective elements to suppress line conducted interference. Figure 26 shows the block diagram of a suitable application circuit. Details are discussed in the following sections.

Please note that the KMI16/x sensors already provide a digital output implemented as an open collector. As these modules can operate at 5V supply voltage, the standard level for digital systems, these types should be preferred in digital systems if the advantages of the two-wire current interface are not that important.

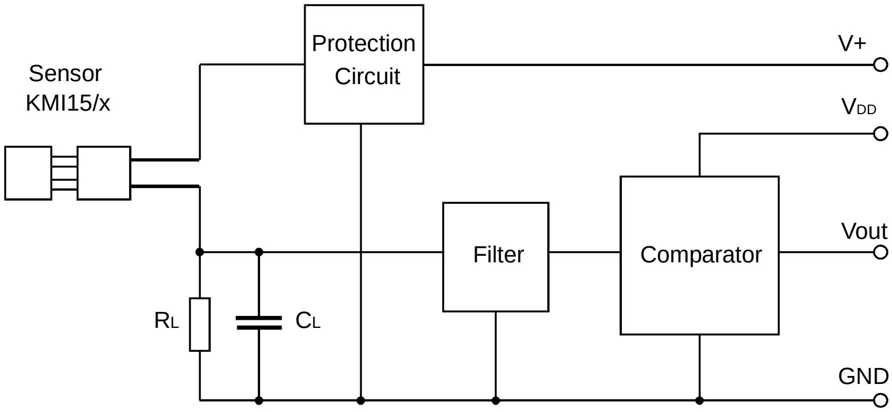

Figure 26: Block diagram of a suitable application circuit

Please note that the KMI16/x sensors already provide a digital output implemented as an open collector. As these modules can operate at 5V supply voltage, the standard level for digital systems, these types should be preferred in digital systems if the advantages of the two-wire current interface are not that important.

7.2 The Comparator

Figure 27 illustrates the output current levels regarding nominal values and specified tolerances.

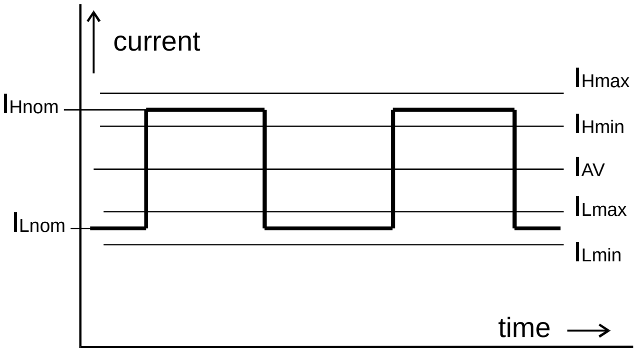

Figure 27: Current levels of the rectangular output signal

Using the recommended series resistor of 115 Ω, the current levels are converted into voltages as given in TABLE 5. Consequently, the comparator levels of a processing electronic must be set between V_{Hmin} and V_{Lmax} for reliable operation. This is ensured by using a reference level of V_{AV} . Additionally, a hysteresis should be implemented.

Symbols Current	**Current in mA**	**voltage in V @ R = 115 Ω**	**Symbols Voltages**
I_{Lmin}	5.6	0.64	V_{Lmin}
I_{Lnom}	7	0.81	V_{Lnom}
I_{Lmax}	8.4	0.97	V_{Lmax}
I_{AV}		1.13	V_{AV}
I_{Hmin}	11.2	1.29	V_{Hmin}
I_{Hnom}	14	1.61	V_{Hnom}
I_{Hmax}	16.8	1.93	V_{Hmax}

TABLE 5: Output current and voltage levels for R = 115 Ω

The complete circuit diagram proposed for such an application is depicted in Figure 28. The dimension is made assuming a 5V supply voltage (V_{DD}) for the comparator. The reference voltage V_{AV} is defined by voltage divider R5/R6. The voltage divider R9/R10, the feed back resistor R7 and the input resistors R2 and R3 determine the hysteresis of about +/- 50 mV.

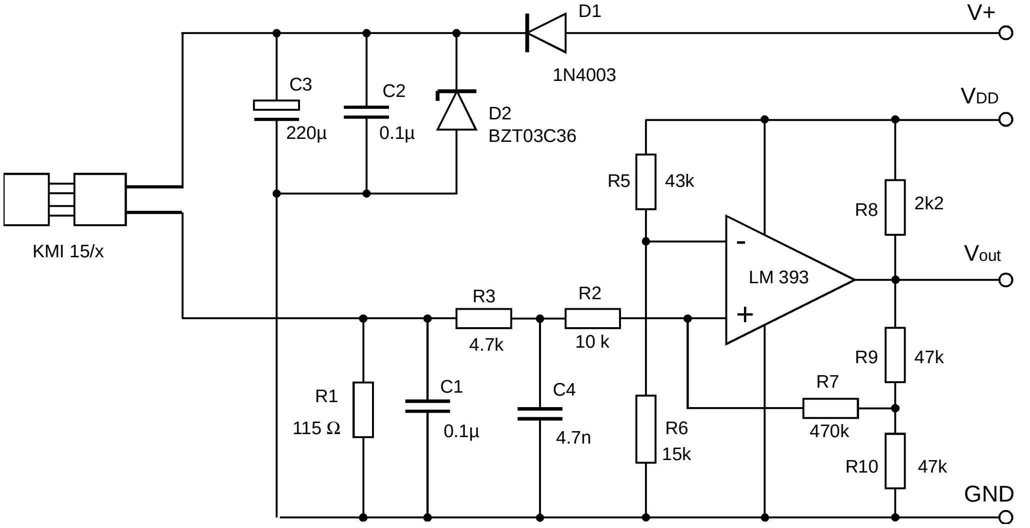

Figure 28: Complete application circuit for digital signal processing with the KMI 15/x sensor modules

7.3 Signal Filter

In addition to the parallel capacitor C1, a second lowpass filter is recommended to reduce RF interference. The example circuit in Figure 28 provides a first-order RC low pass filter for this task (R3, C4) with a cut off frequency of 10 kHz. This cut off frequency should be adapted according to the maximum signal frequency required in the application in order to achieve an optimum absorption of noise.

7.4 Protection Circuit

This part of the circuit has already be described in section 0. The series diode D1 protects the sensor and electronics against reverse polarity of the supply voltage and blocks negative interference pulses. The suppressor diode D2 limits positive interference pulses. Note that the specified type has not the capability to tolerate the load dump pulses. The capacitor C2 absorbs fast positive and negative interference pulses. The electrolytic capacitor C3 stores energy to supply the sensor during short supply voltage breakdown due to negative pulses.

8. OTHER APPLICATIONS

The primary application area of the KMI sensors is rotational speed measurement in automotive applications such as ABS, ASR or gearbox. However, the magnetoresistive rotational speed sensors of the KMI-family are not limited to automotive applications. Their characteristic recommends them for a wide range of general industrial applications. Another range of industrial applications is the detection of non-periodic or single events, where a movement can be transferred to a change of a magnetic field. Examples are:

- Proximity switch
- Position detector
- Limit switch
- Detection of electrical current levels

The common operating principle of these applications is that a moving ferromagnetic part, a moving permanent magnet or changes of the electrical current cause an alteration of the magnetic field measured by the MR sensor and, in consequence, forces an alteration of the output signal. The sensors of the KMI family offer simple, reliable and cost effective solutions also for this kind of applications.